An Inertial Pen with Dynamic Time Warping Recognizer for Handwriting and Gesture Recognition

[#1]K.N.Tirth, [#2]Prof. Y.S. Angal

[1]kirtitrth19@gmail.com
[2]yogeshangal@yahoo.co.in

[#1]Student, Department of Electronics & Telecommunications
[#2]Professor, Department of Electronics & Telecommunications
JSPM's
Bhivrabai Sawant Institute of Technology & Reasearch Wagholi ,Pune, India.

ABSTRACT

This paper presents an inertial-sensor-based digital pen (inertial pen) and its associated dynamic time warping (DTW)-based recognition algorithm for handwriting and gesture recognition. Users hold the inertial pen to write numerals or English lowercase letters and make hand gestures with their preferred handheld style and speed. The inertial signals generated by hand motions are wirelessly transmitted to a computer for online recognition. The proposed DTW-based recognition algorithm includes the procedures of inertial signal acquisition, signal pre-processing, motion detection, template selection, and recognition. We integrate signals collected from an accelerometer, a gyroscope, and a magnetometer into a quaternion-based complementary filter for reducing the integral errors caused by the signal drift or intrinsic noise of the gyroscope, which might reduce the accuracy of the orientation estimation. Furthermore, we have developed a minimal intra-class to maximal inter-class based template selection method (min-max template selection method) for a DTW recognizer to obtain a superior class separation for improved recognition. Experimental results have successfully validated the effectiveness of the DTW-based recognition algorithm for online handwriting and gesture recognition using the inertial pen.

Keywords: **Inertial pen, dynamic time warping, quaternion-based complementary filter, handwriting recognition, gesture recognition.**

ARTICLE INFO

I. INTRODUCTION

With the rapid development of computer technology, contemporary human-computer interaction (HCI) devices/techniques have become indispensable in individuals' daily lives. HCI devices/techniques have also dramatically altered our living habits with computers, consumer electronics, and mobile devices. The ease with which an HCI device or technique can be understood and operated by users has become one of the major considerations when selecting such a device. Therefore, it is necessary for researchers to develop advanced and user-friendly HCI technologies which are able to effortlessly translate users' intentions into corresponding commands without requiring users to learn or accommodate to the device. Technologies are being developed which are able to intuitively express users' intentions, such as handwriting, gestures, and human body language, to

naturally control HCI devices. These technologies have many applications in the fields of remote control, virtual reality, sign language, signature authentication, sport science, health care, and medical rehabilitation. Recently, a number of researchers have developed diverse technologies for inertial-sensing-based HCI methods such as activity recognition, gesture recognition, handwriting recognition, and motion tracking. Among inertial-sensing-based HCI methods, pen-based input devices embedded with accelerometers and/or gyroscopes can most easily provide intuitive expressions through capturing translational accelerations and/or angular velocities generated by hand movements.

Most importantly, inertial-sensing-based pen-based input devices for recognizing handwritten characters and hand gestures can be operated without ambit limitations such as writing ranges, directions, or dimensions, while other pen-based devices such as

electromagnetic and pressure types must limit the writing space. The major challenge of inertial-sensing-based handwriting and gesture recognition using acceleration or angular velocity signals is misrecognition, since different users have different preferred speeds and styles. Recent studies have shown that hidden Markov model (HMM) and neural network approaches are effective at increasing the recognition rate of the inertial sensing-based handwriting and gesture recognition. However, the computational complexity of HMMs and neural classifiers are directly proportional to the dimension of the feature vectors, and both require more than one training sample to obtain acceptable recognition rates. While some researchers have demonstrated the effectiveness of the DTW algorithm, which selects the best match from many samples for each class for recognition, most of these studies were based on accelerometer-based gesture recognition alone. For example, described an accelerometer-based gesture recognition system for categorizing 3700 samples collected from seven subjects. The system employed the DTW with affinity propagation methods to obtain class templates for each gesture during the training phase. The accuracy for recognizing eight gestures reached 96.84% and 100% for user-independent and user-dependent recognition, respectively. Used a triaxial accelerometer with a DTW algorithm for personalized gesture recognition. Over 4000 samples with eight gestures collected from eight users were utilized for user-dependent recognition with 98.6% accuracy. In this paper, an inertial-sensor-based digital pen (inertial pen) and a dynamic time warping (DTW)-based recognition algorithm are presented for both handwriting and gesture recognition tasks. The portable inertial pen is composed of a triaxial accelerometer, a triaxial gyroscope, a triaxial magnetometer, a microcontroller, and an RF wireless transmission module. Users can utilize this inertial pen to write numerals or English lowercase letters, and make hand gestures at their preferred speed without any space limitations. Measured accelerations, angular velocities, and magnetic signals are transmitted to a personal computer (PC) via the RF wireless module. The proposed DTW-based recognition algorithm is composed of the procedures of inertial signal acquisition, signal preprocessing, motion detection, template selection, and recognition. In the proposed recognition algorithm, we utilize the zero velocity compensation (ZVC) method and a quaternion-based complementary filter to reduce the integral errors caused by the intrinsic noise/drift of the accelerometer and gyroscope, which worsen the accuracy of the velocity, position, and orientation estimations. Furthermore, we have developed a minimal intra-class to maximal inter-class based template selection method (Min-Max template selection method) for a DTW recognizer to obtain a superior class separation for improved recognition.

II. PREVIOUS WORK

"A Review on Frequent Pattern Mining" by Vivek B. Satpute proposed Pattern mining in recent times achieved major importance in the data mining community for the reason of its ability of being used as very important tool for the knowledge discovery and its applicability in the other data mining jobs like classification and clustering. Association rules are always of interest to the both database community as well as data mining users. Here a survey have provided of previous studies made in this area and recognize some vital gaps available in the current knowledge.

In "Analysis of Frequent Item sets and Pattern Sets Mining Algorithms" proposed Frequent itemsets play an essential role in many data mining tasks that try to find interesting patterns from databases, such as association rules, correlations, sequences, episodes, classifiers, clusters and many more. Many researchers invented ideas to generate the frequent item sets. The time required for generating frequent item sets plays an important role. Some algorithms are designed, considering only the time factor. Our study includes depth analysis of algorithms and discusses some problems of generating frequent item sets (pattern sets) from the algorithm. The unifying feature among the internal working of various mining algorithms is explored. Some Frequent pattern mining often produces a large number of frequent patterns, which imposes a great challenge on visualizing, understanding and further analysis of the generated patterns. This emerges the need for finding small number frequent occurring patterns. In this paper, we explain the basic frequent item set, pattern sets mining problems. We describe the main techniques used to solve these problems and give a comprehensive survey of the most influential algorithms that were proposed during the last decade.

"Efficient Analysis of Pattern and Association Rule Mining Approaches" paper proposed the process of data mining produces various patterns from a given data source. The most recognized data mining tasks are the process of discovering frequent item sets, frequent sequential patterns, frequent sequential rules and frequent association rules. Numerous efficient algorithms have been proposed to do the above processes. Frequent pattern mining has been a focused topic in data mining research with a good number of references in literature and for that reason an important progress has been made, varying from performant algorithms for frequent item set mining in transaction databases to complex algorithms, such as sequential pattern mining, structured pattern mining, correlation mining. Association Rule mining (ARM) is one of the utmost current data mining techniques designed to group objects together from large databases aiming to extract the interesting correlation and relation among huge amount of data. In this article, we provide a brief review and analysis of the current status of frequent pattern mining and discuss some promising research directions. Additionally, this paper includes a comparative

study between the performances of the described approaches.

III. ALGORITHM USED

DTW algorithm:

In time series analysis, dynamic time warping (DTW) is an algorithm for measuring similarity between two temporal sequences which may vary in time or speed. For instance, similarities in walking patterns could be detected using DTW, even if one person was walking faster than the other, or if there were accelerations and decelerations during the course of an observation. DTW has been applied to temporal sequences of video, audio, and graphics data indeed, any data which can be turned into a linear sequence can be analyzed with DTW. A well-known a11111pplication has been automatic speech recognition, to cope with different speaking speeds. Other applications include speaker recognition and online signature recognition. Also it is seen that it can be used in partial shape matching application.

In general, DTW is a method that calculates an optimal match between two given sequences (e.g. time series) with certain restrictions. The sequences are "warped" linearly in the time dimension to determine a measure of their similarity independent of certain non-linear variations in the time dimension. This sequence alignment method is often used in time series classification. Although DTW measures a distance-like quantity between two given sequences, it doesn't guarantee the triangle inequality to hold.

The proposed DTW-based recognition algorithm includes the procedures of inertial signal acquisition, signal pre-processing, motion detection, template selection, and recognition.
Dynamic time warping (DTW) is a well-known technique to find an optimal alignment between two given (time-dependent) sequences under certain restrictions.
Intuitively, the sequences are warped in a nonlinear fashion to match each other. Originally, DTW has been used to compare different speech patterns in automatic speech recognition. In fields such as data mining and information retrieval, DTW has been successfully applied to automatically cope with time deformations and different speeds associated with time-dependent data.

IV. PROPOSED DESIGN

1) With the inertial pen, users can deliver diverse commands through hand motions to control electronic devices anywhere without space limitations.

2) The DTW-based recognition algorithm only requires one training sample or class template for each class for highly accurate motion recognition; and

3) The DTW-based recognition algorithm can effectively reduce the integral errors of inertial signals.
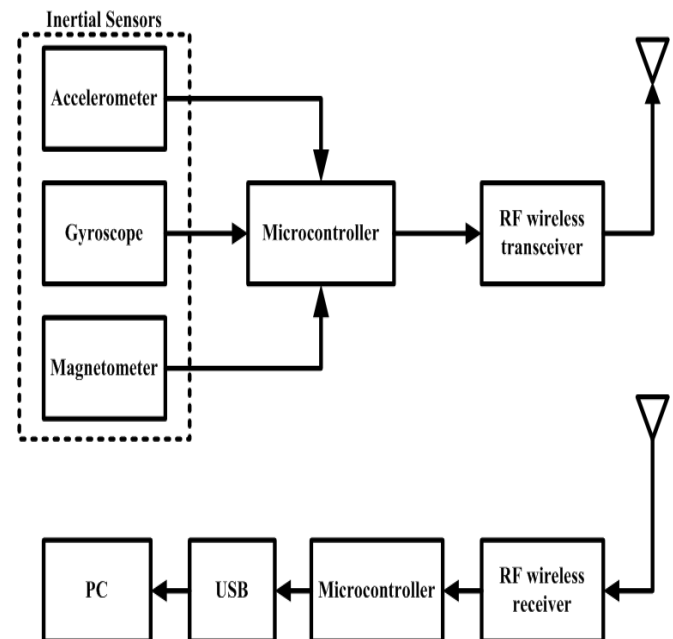
Our inertial pen consists of a triaxial accelerometer (LSM303DLH, STMicroelectronics), a triaxial gyroscope (L3G4200D, STMicroelectronics), a triaxial magnetometer (LSM303DLH, STMicroelectronics), a microcontroller (STM32F103T8, STMicroelectronics), and an RF wireless transceiver (nRF24L01, Nordic). The accelerometer, gyroscope, and magnetometer are used to detect accelerations, angular velocities, and magnetic signals generated by hand movements. The LSM303DLH possesses a linear acceleration full scale of $\pm2g$, $\pm4g$, and $\pm8g$, with data output rates from 0.5 Hz to 1 kHz for all axes, and a magnetic field full scale of ±1.3, ±1.9, ±2.5, ±4.0, ±4.7, ±5.6, and ±8.1 gauss, with data output rate from 0.75 Hz to 75 Hz. The accelerometer's sensitivity is set from -4g to +4g in this study. The L3G4200D gyroscope simultaneously detects the X-, Y-, and Z-axis angular rates of the inertial pen, possesses a full scale of ±250, ±500, and ±2000 degree per second (dps) with data output rates from 100 Hz to 800 Hz, and is capable of measuring rates with a user-selectable bandwidth.

The microcontroller collects the digital accelerations, angular velocities, and magnetic signals, and transmits wirelessly the above mentioned inertial signals to a PC main processor via the RF wireless transceiver for further signal processing and analysis. The sampling rate of the abovementioned measurement signals is set at 75 Hz. The size of the pen-type board is 130 mm × 15 mm × 8 mm. Note that all signal processing

procedures are performed on a PC. The overall power consumption of the hardware device is 30 mA at 3.7 V. The battery of the inertial pen is replaceable and rechargeable.

V. OBJECTIVE OF PROPOSED

Most importantly, inertial-sensing-based pen-based input devices for recognizing handwritten characters and hand gestures can be operated without ambit limitations such as writing ranges, directions, or dimensions, while other pen-based devices such as electromagnetic and pressure types must limit the writing space.

The major challenge of inertial-sensing-based handwriting and gesture recognition using acceleration or angular velocity signals is misrecognition, since different users have different preferred speeds and styles.

VI. CONCLUSION

Up till now we have studied basic information of project. I have selected the components for hardware design and drawn the circuit diagram. I have also created the layout of digital pen which will successfully working. Our proposed algorithm for this project is DTW algorithm.

In project phase II, I plan to design, develop and implement a minimal intra-class to maximal inter-class based template selection method (min-max template selection method) for a DTW recognizer to obtain a superior class separation for improved recognition

REFRENCES

[1] K. Altun, B. Barshan, and O. Tunçel, "Comparative study on classifying human activities with miniature inertial and magnetic sensors," Pattern Recognit., vol. 43, no. 10, pp. 3605–3620, 2010.

[2] A. Akl, C. Feng, and S. Valaee, "A novel accelerometer-based gesture recognition system," IEEE Trans. Signal Process., vol. 59, no. 12,pp. 6197–6205, Dec. 2011.

[3] W. C. Bang, W. Chang, K. H. Kang, E. S. Choi, A. Potanin, and D. Y. Kim, "Self-contained spatial input device for wearable computers," in Proc. IEEE Int. Conf. Wearable Comput., Oct. 2003, pp. 26–34.

[4] G. Bailador, C. Sanchez-Avila, J. Guerra-Casanova, and A. de Santos Sierra, "Analysis of pattern recognition techniques for in-air signature biometrics," Pattern Recognit., vol. 44, nos. 10–11, pp. 2468–2478,2011.

[5] C. M. N. Brigante, N. Abbate, A. Basile, A. C. Faulisi, and S. Sessa,"Towards miniaturization of a MEMS-based wearable motion capture system," IEEE Trans. Ind. Electron., vol. 58, no. 8, pp. 3234–3241,Aug. 2011.

[6] M. J. Caruso, "Application of magneto resistive sensors in navigation systems," in Proc. SAE, 1997, pp. 15–21.

[7] R. Xu, S. Zhou, and W. J. Li, "MEMS accelerometer based nonspecificuser hand gesture recognition," IEEE Sensors J., vol. 12, no. 5,pp. 1166–1173, May 2012.

[8] Z. Dong, C. Wejinya, and W. J. Li, "An optical-tracking calibration method for MEMS-based digital writing instrument," IEEE Sensors J.,vol. 10, no. 10, pp. 1543–1551, Oct. 2010.

[9] M. H. Ko, G. West, S. Venkatesh, and M. Kumar, "Using dynamic time warping for online temporal fusion in multisensory systems," Inform. Fusion, vol. 9, no. 3, pp. 370–388, 2010.

[10] Y. S. Kim, B. S. Soh, and S. G. Lee, "A new wearable input device: SCURRY," IEEE Trans. Ind. Electron., vol. 52, no. 6, pp. 1490–1499, Dec. 2005.